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著者	Sawano Nobuhiro
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Pursuing Changes on Sandy Beach Environment by using Geo-informatics: Case of Nakhodka Oil Spill incident

NOBUHIRO SAWANO

Seiryō Women's Junior College

Tori-1, Goshomachi, Kanazawa, Ishikawa Pref. 920-0813, JAPAN

Abstract – Nakhodka oil spill happened in January 1997, more than 2,000 km of shoreline facing the Sea of Japan was contaminated by heavy oil. Soon after the oil stranded on the beach in Kaga city, more than 70 heavy construction machines were introduced for recovering oil. After the recovery works, about 1,800 m³ of “oiled sand” was made and most part of them was buried at the beach. Four years after the spill and recovery works, steep dune scarp have appeared and sand erosion occurred. These phenomena are thought to be brought about the deprivation of vegetation caused by the recovery works.

I. The outline of “Nakhodka”

On January 2nd, 1997, Russian tanker named Nakhodka was navigating from Shanghai to Petrohabavlovsk-Kamchatski carrying 19,221 kiloliters of heavy C oil cargo. It has passed 27 years after she was built. Because of the aging and poor ship maintenances, her strength was decreased to two thirds of original construction strength. Furthermore, the cargo oil was not loaded properly. The arrangement was so inadequate that the resulting longitudinal bending moment was twice the value corresponding the normal cargo oil arrangement specified in the tanker's operational manual.

In addition to aging, poor ship management and inadequate loading, the final trigger was pulled by the fierce gale of the winter weather of the Sea of Japan. She could not bear the bending moment caused by 7 to 8m effective wave height and over 30m wind speed, she broke into two sections approximately 100 kilometers off Oki Island. Main section sank to the sea floor and bow section was drifting for five days about 250 kilometers, finally grounded at Mikuni Town, Fukui Prefecture (see Figure 1 and 2).

By this tanker accident, total about 8,660 kiloliters of oil was spilled. This amount is the second biggest in the Japanese oil spill history. Soon after the accident occurred, Japan Coast Guard announced the spill amount was 6,240 kiloliters as an official figure. But this figure does not include the amount while the bow section was drifting and subsequent grounding.

Spilled oil affected more than 2,000km of coastline including over 9 prefectures and 88 cities and towns. Japan has not prepared nation level contingency plans for stranded oil, as a result, countermeasures were taken to fit the needs of the moment with little formal planning. Over seven hundred thousand volunteers from all over the country took

part in the oil recovery works (Sawano, 1998).

The many parties affected by the spill claimed losses totaling 35 billion yen to the IOPCF (International Tanker Owners Pollution Federation Ltd.) as compensation for the recovery works of oil and the loss of income. IOPCF decided to pay a maximum of 23.3 billion yen, however, evaluation of this claim has been continuing and 60% of the claim was temporarily paid to some parties as of June 1999.

It has passed more than four years, but some beaches, particularly in Noto Peninsular, still remains heavy contamination by this oil spill (Sawano, 2000).

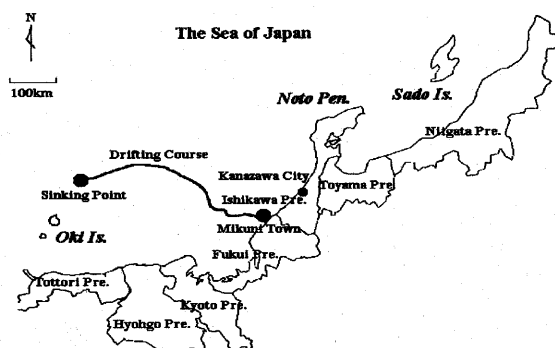


Fig. 1. Location of the Nakhodka Oil Spill



Figure 2. Bow section drifting toward Fukui Prefecture.
(Presented by Hokkuriku Chunichi Shinbun Co., Ltd.)

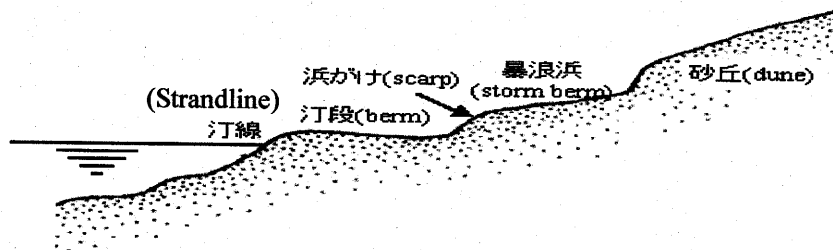


Fig. 4 Typical vertical structure of the sand beach facing the Sea of Japan

II. Sand Beach Shioya and Katano

Shioya and Katano beaches in Kaga City (see figure 3), about 4 kilometers of beautiful sand beach, should be one of the typical examples for many inadequate countermeasures for the oil recovery in the case of Nakhdoka.

Originally, sand beaches in these areas have similar vertical structure shown in figure 4. Small tidal as to 40 cm can be considered as a main factor to develop such structure.

On January 7th, 1997, soon after the oil stranded on the beach, staff members of local society started to clean up the beached oil with more than 70 construction machines like power shovels. Because of the inability of the equipment to separate oil and sand, they ended up making over 18,000 m³ of oil mixed with sand. Some part of oiled sand was tried to sieve to get the tarred oil out by many volunteer workers but they could rid only 377 m³ of oiled sand (see Figure 5 and 6).

Finally, more than 10,000 m³ of unprocessed oiled sand was left and buried at the beach. Such oil and sand could be seen on the surface of the beach even five years after the spill.



Fig 5. Recovery works done on the beach (1)
(Presented by Marine Disaster Prevention Center)

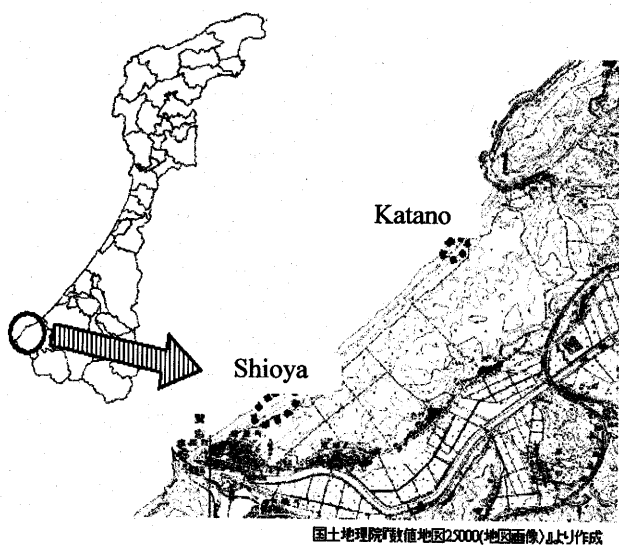


Fig.3 Location of Shioya and Katano

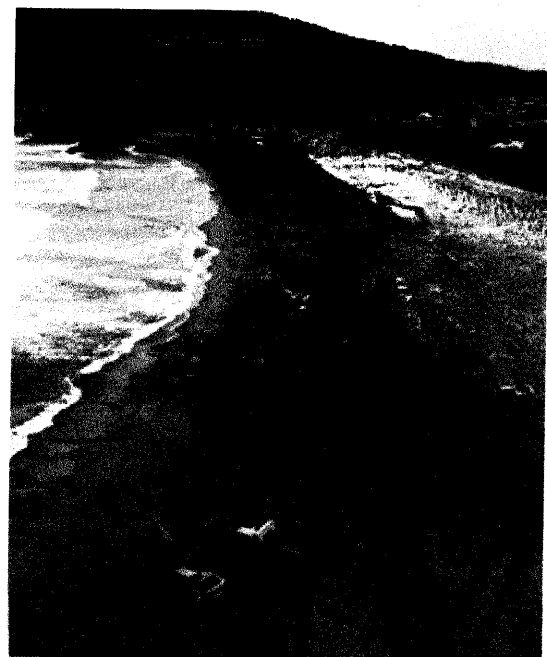


Fig 6. Recovery works done on the beach (2)
(Presented by Hokkoku Shinbun Co., Ltd.)

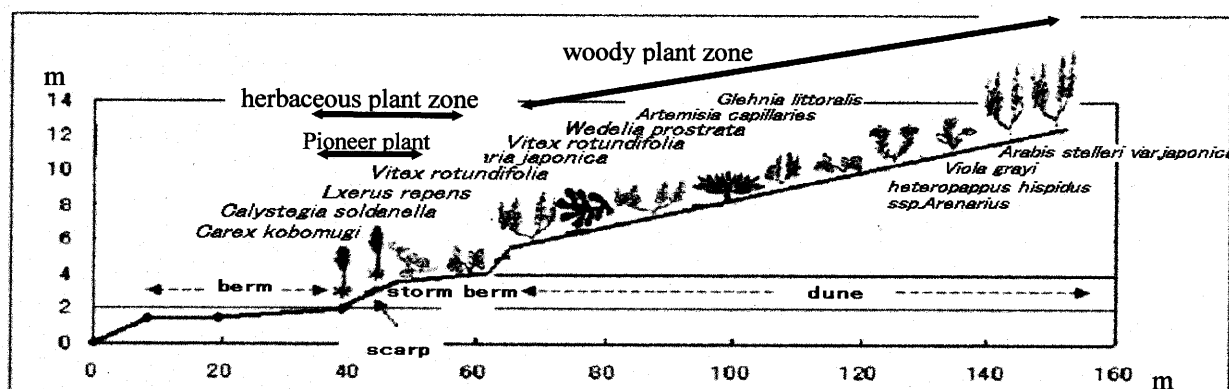


Fig. 7 Zonation for vertical section at Shioya and Katano before oil spill

A. Plant species

Both Shioya and Kantano (these "beaches" are the same continuous beach, actually southwestern part is called "Shioya" and northeast part is called "Katano") are well known for their valuable plant habitat. As of May 1998, 23-kind plant species were confirmed (See table1).

In these areas, many coastal pristine environments had remained before the oil spill, with unique coastal forms of life. Three of them are local level endangered and conservation species. *Hamabengiku*, a kind of chrysanthemum (*Heteropappus hispidus* ssp. *Arenarius*) and *Ishosumire*, a kind of violet (*Viola grayi*), those vegetation communities are endangered all over Japan.

Not only plant species, *Iso-komori-gumo* (*Lycosa isikariana*), *Kisuji-tsuchi-sugari* (*Cicindela arenarias*) and *Kawara-awafuki-bachi* (*Dienoplus tumidus*) are also endangered spiders and bees, which strictly depend on the clean sand beaches in these areas.

B. Zonation

In most costal zone covered with vegetation, different species dominate certain band of zones which are clearly delimited from the others. This characteristics zonation pattern is said to be resulted from the competitive advantages of moisture content, salinity and other physical conditions.

Clear vegetative zonation along the vertical section can be seen on this beach. From the central part of the storm berm, we can see a few kinds of herbaceous plants such as Kobomugi (*Carex Kobomugi*) and Hamahirugao (*Calystegia soldanella*) as pioneer plants. Hamagou (*Vitex rotundifolia*), one of the nann-woody plants is dominated and covered with the rear part of storm berm to the hillside of the dune with high density. Upper part of the dune is covered with herbaceous plants again such as Isosumire (*Vila grayi*).

Figure 7 shows the schematic diagram of typical zonation before the oil spill and recovery works on this beach.

Table 1. List of plant species

Japanese Name	Botanical Name
Hinezu**	<i>Juniperus conferta</i>
Gyoungishiba	<i>Cynodon dactylon</i>
Kekamonohashi	<i>Ischaemum antheophoroides</i>
Kouboumugi	<i>Carex kobomugi</i>
Kouboushiba	<i>Carex pumila</i>
Okahijiki	<i>Salsola komarovii</i>
Aotsuzurafuji	<i>Cocculus trilobus</i>
Hamahatazao	<i>Arabis stelleri</i> var. <i>japonica</i>
Nemunoki	<i>Albizia julibrissin</i>
Akigumi	<i>Elaeagnus umbellate</i>
Anamasumire	<i>Viola mandshurica</i> var. <i>crassa</i>
Isosumire**	<i>Viola grayi</i>
Mematsuyoigusa	<i>Oenothera biennis</i>
Hamaboufu**	<i>Glehnia littoralis</i>
Hekusokazura	<i>Paederia scandens</i>
Nenashikazura	<i>Cuscuta japonica</i>
Hamahirugao	<i>Calystegia soldanella</i>
Hamagou	<i>Vitex rotundifolia</i>
Funakisou	<i>Scutellaria strigillosa</i>
Unran	<i>Linaria japonica</i>
Kawarayomogi	<i>Artemisia capillaries</i>
Nekonoshita	<i>Wedelia prostrate</i>
Hamabenogiku	<i>Heteropappus hispidus</i> ssp. <i>Arenarius</i>

** Local level species to protection

III. Methods for Pursuing Changes

One year after the oil spill and recovery works, it appeared recession of the plant vegetation as well as the sand erosion of the berm. Figure 8 and 9 were taken at almost the same point and angle. Comparing with these two pictures, storm berms and plants were completely disappeared as of May 2001 at this area.

For pursuing changes of the sand beach and beach profile, we tried setting tens of gardening stakes along the pioneer plants first. But those efforts were in vain because most stakes were flown away with the shifting sand in winter.



Fig. 8 Katano beach in September 1998



Fig. 9 May 2001 (Same angle as Fig.8)

A. Baseline

"Baseline data" is very important to know the circumstances before the accident. Generally, these data are very few and almost impossible to obtain.

Fortunately, Japan Map Agency has been taking aeronautical pictures for making maps almost every ten years after the World War II, and in these pictures, we can identify the lines of the pioneer plants.

These images are scanned by hi-resolution optical scanner, and image data are geo-corrected by Geographical Information System (GIS). By these processes, geo-corrected images are overlaid each other then can be compared on the same coordinate.

B. dGPS for recoding the location of the pioneer plants

dGPS (differential Global Positioning System) system involves the cooperation of two receivers; one that is stationary and another is roving around making position measurements. Most popular dGPS system is using mid-wave broadcast for the stationary part. Japan Coast Guard has started this broadcast in April 1999. This system is designed for marine navigation, but this signal can be received all over the country including mountainous area.

Carrying roving port of the system and data-logging computer on/along the target, positional information can be stored automatically. Positioning precisions come to be less than 1.0m (In the case of independent GPS, reliable precision is said to be about 10m). Figure 10. shows the actual scene of using this system for positioning the pioneer plants at Shioya beach.



Fig. 10 On-site survey for measuring pioneer plants using dGPS

D. Land measurement

Land measurement survey has been started in May 1998, one year after the spill. This survey is conducted in each season, four times a year. Main purpose of this survey is to confirm the changes of the shoreline topology then bearing out the relation between the recessions of the vegetation.

In this survey, base line for the measurement is set by the stable reference points such as stone markers on the beach using Total Stations (TS). After the base line is fixed, measuring points are set along this line also using TS (see figure 11). Measuring points are set with 10m-grid interval, 100-150m along the strandline. For the vertical direction, the base line is also extended 40m toward the hillside of the dune. Total number of measuring point is 60 for Shioya, 40 for Katano. Precision for setting measuring point should be less than 1cm in each survey.

After all measuring points are fixed, elevation is measured at all these points by level and staff (see figure 12).

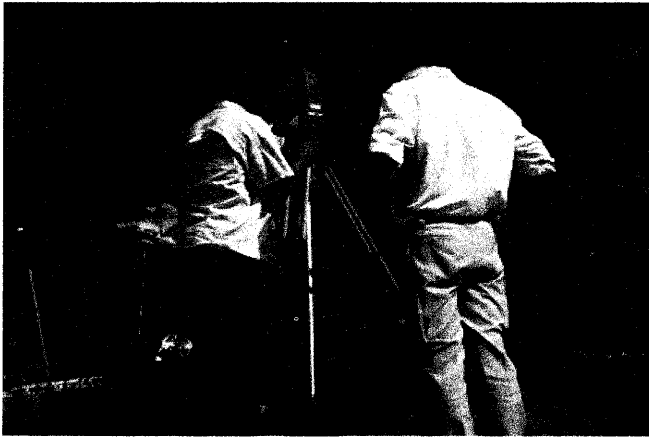


Fig. 11 Setting the base line using TS and stable land markers



Fig. 12 Staff and level are used for measuring elevation

A. Changes of the location of pioneer plants comparing with the baseline

Positional data of the pioneer plants extracted from the aeronautical pictures and on-site researches using dGPS, both of them are overlaid and compared by the GIS.

In the figure 11, area A, B and C show the recessed vegetation area comparing with 1994 and 1999, 2000 and 2001 respectively. Figure 10 only shows the central part of this beach, then table 2 summarizes the areas progressed (moving toward the strandline) and recessed comparing with the line as of 1994 and 1999, 2000 and 2001.

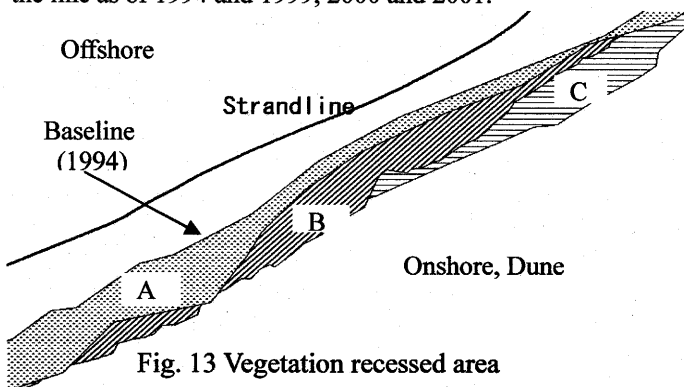


Fig. 13 Vegetation recessed area

Table.2 Area comparing with the baseline of 1994

Year	Progressed	Recessed	Progressed - Recessed
1999	7486.68	17168.31	-9681.63
2000	7869.2	30130.96	-22261.77
2001	5297.27	24699.42	-19402.16

(unit: m²)

A. Land measurement

Fifteen times of land measurement survey has been conducted until now. Data are divided into three groups with series as follows.

1. May 1998 - November 1999
2. May 1999 - July 2001
3. September 2001 - November 2002

Standard deviation (S.D.) of the elevation for each measuring point is calculated. Figure 14's red (grey) area shows the measuring points whose S.D. is more than 20cm at Shioya.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	Z
m-2																
m-1																
m																
s+1																
s+2																

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	Z
m-2																
m-1																
m																
s+1																
s+2																

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	Z
m-2																
m-1																
m																
s+1																
s+2																

Fig. 14 Measuring points whose S.D. is over 20cm

Note: Top table :May 1998-Nov. 1999

Middle table : May 1999-Jul. 2001

Bottom table: Sep. 2001-Nov. 2002

Horizontal direction is along the strandline, "s" is toward the strandline and "m" toward the dune.

From the research for the location of pioneer plants, it has confirmed that vegetation has been recessed comparing with the two states before and after the accident.

From the survey of the land measurement, it has turned out that the area in which the standard deviation of altitude has become larger, namely, unstable area has been expanded in this beach. Moreover, vegetation does not grow on such unstable area, then two phenomena, one is recession of vegetation, the other is enlargement of unstable area, are

advancing simultaneously after the accident on this beach.

Most probable scenario of collapse of the beach is as follows:

Oil recovery works using heavy machinery was done just along the line of pioneer plants (see figure 5 and 6 again). By these works, plant vegetation was totally destroyed. These pioneer plants have strong roles for the formation and stabilization of the sand beach. These plants trap and hold windblown sand in the foredune and help create condition with encourage the establishment and growth of other plant communities. All plants, whether they are herbs, shrubs or trees, growing either singly or in groups, have a role in the development of vegetative cover and together they bring about dune stabilization. Anyway, all was thought to be due to the recovery works done by heavy machinery.

VI. Conclusion

Vulnerability of the coastal environment by oil spill has already summarized by the researches by Glundlach and his colleagues in mid 1970's to 1980's. Today, NOAA (National Oceanic and Atmospheric Administration) publishes the recommended recovery works for sand beach. According this guideline, in case of recovery works on sand beach, oil and sand mixing have to be avoided and special attention have to be taken for protection of the vegetation. They all for the protection of sand beach erosion and coastline recession.

Lessons of the world biggest tanker oil spill of Amoco Cadiz happened in France in 1978, quite the same situation occurred and it had reported that they faced a big-scaled sand erosion after recovery works done by heavy machinery.

Our Nakhodka's case is an only repetition of Amoco Cadiz and our research work is only to "reconfirm" their research. Learning from the actual experience and prepare for the "next", this is the only way to face the accident.

Acknowledgements

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